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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

Express Mail Label N . EV 312 068 343 Date f Deposit: F bruary 2, 2004

INVENTOR(S)

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☐ *Additional inventors are being named on the _____ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

USING RANDOMIZED HOUGH TRANSFORM FOR DETECTING RADIO SYSTEMS WITH PERIODIC EMISSION PATTERN

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ENCLOSED APPLICATION PARTS ***(check all that apply)***

☒ Specification *Number of Pages* 6 ☐ CD(s), Number

☐ Drawing(s) *Number of Sheets* ☐ Other (specify)

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees — FILING FEE AMOUNT ($)

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☐ Payment by credit card. Form PTO-2038 is attached.

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____.

Respectfully submitted,

SIGNATURE [signature] Date FEBRUARY 2, 2004

REGISTRATION NO.: 48,027 *(if appropriate)*

TYPED or PRINTED NAME Aaron Waxler

Docket Number: US040108

TELEPHONE (914) 333-9608

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

Philips Intellectual Property & Standards

Invention Disclosure
Version 1.4.0 14-11-2002

This template is meant for making a detailed description of your invention off-line. The description can then later be attached in electronic form to your ID submission. You must also use this off-line description to obtain export clearance from your local export-control officer.

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Title: Using Randomized Hough Transform for Detecting Radio Systems with Periodic Emission Pattern.

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b. Indicate problems/disadvantages with the state of the art that your invention will overcome. Are the disadvantages/problems new or were they already known?
c. The measures/device features that are proposed to solve the problem, and the resulting advantages. If the invention is based on a new understanding (insight), please indicate this.

d. Provide at least one embodiment of the invention, where you explain the best way of carrying out the invention. Please add drawings, graphs, test data etc. where appropriate.

e. Indicate in which fields (technical, commercial) the invention can be applied.

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On using Randomized Hough Transform for Detecting Radio Systems with Periodic Emission Pattern

As indicated in earlier sections, when *radio networks* encounter *other devices* that emit energy (and therefore use shared radio resources) in their vicinity, it is desirable to characterize the radio resource usage patterns of these other devices. Such a characterization of the usage patterns results in the identification of opportunities for the radio networks. Other devices referred to previously includes radars, which are primary emitters, or other radio networks, which are secondary emitters.

In this section we will examine the use of Hough Transform for the detection of radar pulses as an example for any type of radio signals that create periodic patterns. We will use a version of the Hough Transform, known as Randomized Hough Transform (RHT) to detect the parameters of helixes wrapped around cylinders, as explained later in the section. The Hough Transform [] has been studied in image processing literature for detection of patterns such as lines, circles and ellipses in binary images. The effectiveness of Hough Transform in detecting patterns in ~~"imperfect"~~ data with many overlaying patterns and random noise is proven []. In the presence of outliers, the Hough Transform is more robust than least squares estimation [].

In brief, the Hough Transform is used to transform data from image space to an accumulator (or histogram) in parameter space, as shown in the Figure 1 below.

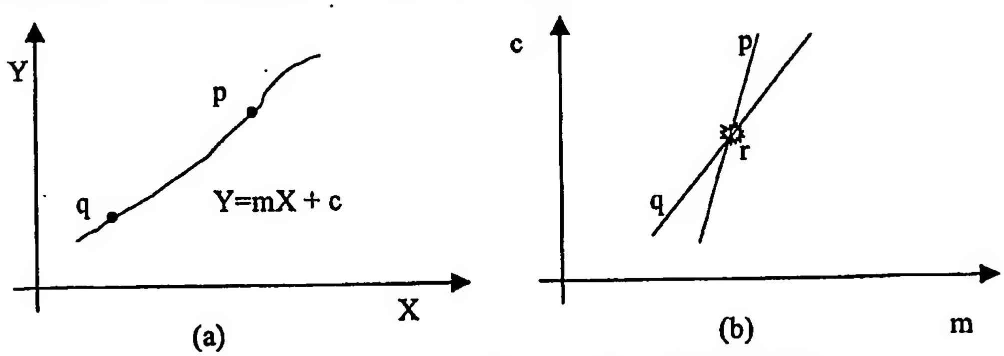

Figure 1: Hough Transform used to detect straight lines (a) image space and (b) parameter space.

The image space is represented by (x, y), whereas, the parameter space is represented by (slope, intercept), that is (m, c). For each point in the image space (e.g. p and q), a line is generated in the parameter space as shown. The parameter space can be seen as a two dimensional histogram. A peak (r) in the parameter space corresponds to a line in the image space. The Hough Transform is robust because in the image space, a collection of collinear points is enough to result in a peak in the parameter space. However, it has the drawback that the parameter space could require large amount of memory in the computer. To address this drawback the RHT was developed. The RHT as applied to straight-line detection, results in randomly picking pairs of points and computing and

accumulating a parameter (for instance, slope). When enough confidence in the peak is achieved, the process stops, thus reducing both memory and processing time.

The use of Hough Transform for radar pulse detection was first studied in []. The original radar pulse train is a 1-D signal. The authors have used 1-D to 2-D transformation (like a raster scan) and then applied the Hough Transform to detect straight lines, which correspond to pulse trains. Furthermore, they have computed the noise floor. We extend their work by first transforming the 1-D signal to a 3-D helical signal, and apply RHT to it.

A helix may be represented by the following parametric equations:

$$X(t) = \sin(\omega t)$$
$$Y(t) = \cos(\omega t) \ldots\ldots\ldots (1)$$
$$Z(t) = t$$

This helix is cylindrical (as opposed to the more general elliptical) and has unit radius.

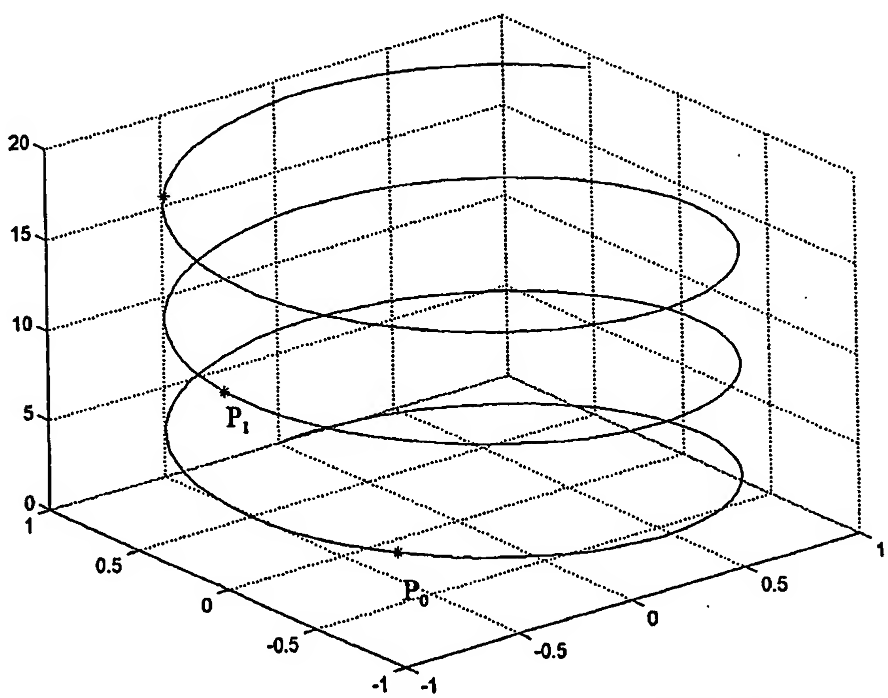

Figure 2: A helix given by the equation 1 above (for ω=1)

Based on the parameter ω a new helix can be generated that wraps around the cylinder more slowly as ω decreases. In Figure 2, the points (red *) on the blue helix themselves form a helix, with an ω value less than one. Given two points on the helix P_0 (x_0, y_0, z_0) and P_1 (x_1, y_1, z_1), the parameter ω can be given by the following equation:

$$\omega = \left(\frac{a\tan(\frac{y_1}{x_1}) - a\tan(\frac{y_0}{x_0})}{z_1 - z_0} \right) \text{............(2)}$$

If the two points P_0 and P_1 are inside one twirl of the helix, then ω works out to be 1. The length of the line segment given by one twirl of helix is

$$l = 2 * \pi * \sqrt{1 + \left(\frac{1}{\omega} \right)^2} \text{............(3)}$$

Results

Let us represent the location (time-of-arrival) of the radar pulse train with the vector L_p. For L_{p1} = [9, 59, 109, 159, 209, 259, 309, 359], the following ω histogram is obtained.

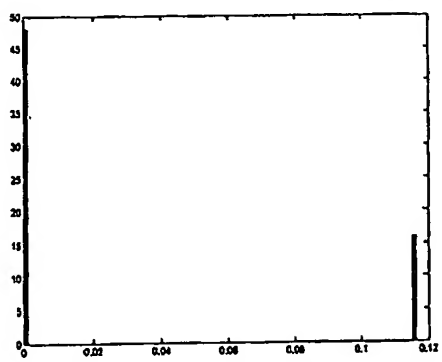

Figure 3: Histogram of ω for L_{p1}

For this case, ω = 0.116. Now let us consider the case where there are two pulse trains that are multiplexed and represented by L_{p2} = [9, 20, 59, 60, 100, 109, 140, 159, 180, 209, 220, 259, 260, 300, 309, 340, 359]. The following histogram is obtained. Note that ω = 1 corresponds to points on the helix within one twirl.

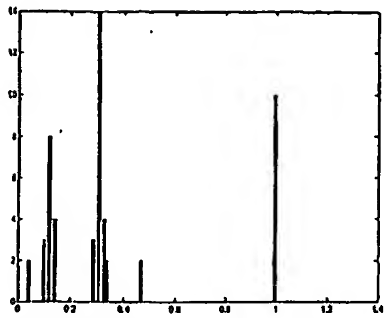

Figure 4: Histogram of ω for L_{p2}.

Potential Extension

The method described in this document may be associated with the alternative way of detection periodic interferences, which is based on the autocorrelation of measurements in time. We expect that both alternatives show advantages and disadvantages in different scenarios, and a combination of both may therefore result in the most precise identification of other radio systems.